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PLATE XII

HON. SIR CHARLES ALGERNON PARSONS, K.C.B., F.R.S., O.M.
Born July 13, 1854; died February 11, 1931

(From a Portrait by Orpen)

SIR CHARLES AND LADY PARSONS

(From a photograph by C. A. Chant taken at Rav, August 25, 1928, during a light rain.)

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SIR CHARLES PARSONS

BY C. A. CHANT

(With Plates XII, XIII)

THE recent death of Sir Charles Parsons, while on a pleasure cruise to the West Indies, came as a shock to his many friends and admirers. Though he had reached a somewhat advanced age, his activity of mind and body gave promise of further years of achievement.

Charles Algernon Parsons was born July 13, 1854, the fourth and youngest son of the third Earl of Rosse, who is famous in astronomical history as the constructor of the six-foot reflecting telescope of Birr Castle, Parsonstown, Ireland. Lord Rosse was born in 1800 and died in 1867. He graduated at Oxford University with first class honours in mathematics, and in later life he was a profound student of economics. While a youth he showed a special taste for mechanics and developed a remarkable manual dexterity.

Having leisure and means Lord Rosse looked about for the best way to employ his mechanical skill. Now Sir William Herschel died in 1822, and Lord Rosse admired exceedingly his skill in building reflecting telescopes as well as in using them. Herschel, it is said, had two hundred failures before he succeeded in making a satisfactory mirror; but ultimately he was able to produce one four feet in diameter, with a focal length of forty feet. Lord Rosse knew well that to construct such large astronomical instruments would try his mechanical ability to the limit, but he deliberately decided to make it the chief business of his life.

The material then used for telescope mirrors was an alloy of copper (two parts) and tin (one part). It is extremely hard and brittle, quite unlike either of its two constituents. It is very difficult to mould and the manipulation of the casting, after it has been made, demands experience and judgment; but it takes a fine polish and does not tarnish quickly.

After much experimenting Lord Rosse, in 1842, undertook to produce a mirror six feet in diameter and five inches thick—far larger than any attempted up to that time. He met many difficulties and had many failures but he would not give up, and the great telescope was completed in 1845. It was a scientific wonder of the world and remained unequalled in size until about fifteen years ago.*

In his father's workshop Charles Parsons learned to love mechanical pursuits. It is on record that in 1868 he and two brothers built a four horse-power steam "horseless carriage," which developed a speed of ten miles per hour; but it figured in an accident to a pedestrian and the father locked it up.

Sir Charles received his early education from the able young astronomers employed by his father to observe with the six-foot reflector—among them being Dr. G. Johnstone Stoney and Sir Robert Ball—and then, after a brief period at Dublin University, he went to Cambridge. In three years he graduated (in 1876) with high honours in mathematics (eleventh wrangler). In the same year he became an apprentice in the Armstrong ordnance works at Elswick, where he remained four years, devoting all his spare time to the study of steam. He next joined Messrs. Kitson, of Leeds, as experimentalist. This company manufactured a rotary engine which he had invented. Here he remained two years, until 1883.

Then he became a member of the firm of Clark, Chapman, Parsons and Co. His work on the rotary engine had directed his attention to the steam turbine. Many had attempted to solve the numerous problems involved in it and had failed, but this did not deter him—perhaps attracted him. He refrained from examining any of the previous patents, but attacked the general problem

*See Reminiscences and Letters of Sir Robert Ball, Ch. VI., 1915.

in his own way—from analogy of the water turbine. On April 23, 1884, he applied for two patents, and the history of the modern steam turbine began. The first patent covered a method of constructing a dynamo to run at the tremendous speed of 18,000 r.p.m.; the second was for a steam turbine on the same shaft, to drive it. Considering the rudimentary condition of electrical theory at that time, the construction of such a generator was an audacious project, while the turbine was entirely new. In less than a year a 4 k.w. dynamo and turbine unit was completed—the first successful turbine ever built.

During the next five years his firm constructed about three hundred turbo-generators of this type, the largest having a capacity of 75 k.w. During all this time Sir Charles laboured strenuously to improve the machines. Becoming somewhat dissatisfied, in 1889 he left the firm, but the latter, as the result of an arbitration, was allowed to retain the patents. The price asked for them was about £98,000, which Sir Charles would not give. Undaunted, in the same year he established the firm of Charles A. Parsons and Co. at Newcastle-on-Tyne, and resolutely set to work to produce a turbine on a different principle. In the original type the steam moved parallel to the axis; in the new one, radially outwards. In three years, in 1892, he produced a larger and more economical machine than the original one, though he still considered the parallel-flow method preferable. However, his old firm was not able to utilize the primary patents and Parsons got them back in 1894 for about £2,000. This gave him great satisfaction.

It was in this year Sir Charles began the application of the turbine to ships. A multitude of new and vexatious difficulties were encountered, arising chiefly from the excessive speed of rotation of the turbines. But one by one they were mastered, and in 1897, he made a grand demonstration of the use of turbines for marine propulsion. He equipped a little vessel, the Turbinia, one hundred feet long and nine feet wide, with engines of about 2,000 h.p., and at the naval review on the occasion of the Diamond Jubilee of Queen Victoria it raced up and down the line of warships at the unprecedented speed of nearly forty miles an hour. This performance drew universal attention to the marine turbine and its use in ships grew rapidly. In 1907 the Mauretania, of 40,000

tons displacement, with the turbine engines of 68,000 h.p., was completed, just ten years after the Turbinia, of 40 tons displacement. At present a great Cunard ship is being build which will have engines of 200,000 h.p.

As early as the nineties Lord Kelvin made the statement that the Parsons turbine was the most important development in steam engineering since the days of James Watt. The years since then have abundantly confirmed the accuracy of this remark.

Sir Charles Parsons had many other interests. One of these was the artificial production of diamonds. In various ways he subjected carbon to enormous pressures and temperatures, but without success. He would seldom give up a method without pushing it to the limit, and it is a pretty safe prediction that no one else will succeed where he failed. On these notable experiments about £30,000 was spent.

From his father Sir Charles inherited an interest in optical work. As early as 1887 he took up the production of mirrors for searchlights. As usual, he improved methods of manufacture, and devised a process for making mirrors up to seven feet in diameter, true to a desired shape. Nearly all the parabolic searchlight reflectors in Great Britain are from the Parsons works at Newcastle. He also made reflectors parabolic in one plane and hyperbolic or elliptical in the plane at right angles. Finding that there were many casualties among these mirrors he undertook an investigation into the glass from which they were made, which led to the production of a special heat-resisting boro-silicate glass, much more suitable for the purpose.

In January, 1921, he secured a large interest in the optical firm of Ross, Limited and became chairman of the Company. Here again his original mind and engineering genius suggested new methods of grinding which led to improvements in manufacture, with increased efficiency and a nearer approach to perfection in the finished products.

It is well known that at the outbreak of the great war Britain lagged far behind in the production of optical glass. This art, in which she was supreme a few decades ago, had been neglected, and the researches of Abbé and Zeiss in Germany had given that country almost a monopoly of this material. During the war the

Derby Crown Glass Works had been established and it had been successful in producing glass of the highest quality; but after the war the urgency was gone and the continuance of the works was problematical. Sir Charles, of course, realized the importance of optical glass in the production of optical instruments; but no doubt his devotion to his country made him view the loss of such an industry with great misgiving. It is also believed that he was attracted by the possibility of making large lenses for telescopes. At any rate in July, 1921, he acquired the Derby Company, and its name was later changed to the Parsons Optical Glass Co. Once more his originality and experimental ability soon brought about many changes. He evolved a method of producing large discs and promptly accepted an order from Sir Howard Grubb and Sons for the flint disc for the 27-inch objective for Johannesburg. He then developed his own methods for much larger discs for lenses. He introduced improvements in the furnace in order to avoid breakage of the melting pot; he devised methods of stirring, thereby obtaining greater homogeneity; he overcame difficulties in handling the melted material and in annealing. In this way he succeeded in producing a pair of discs for a telescope objective 42 inches in diameter—slightly larger than the lenses of the Yerkes refractor. Some work has been done on these discs in the expectation of using them in a refractor for the Russian Soviet government.

The name of Grubb is highly honoured among the makers of astronomical instruments. Thomas Grubb, born in Kilkenny, in 1800, early in the century established a shop near Dublin. Among his products was the original equipment for nearly forty magnetic stations, one of which was established in Toronto in 1840, and has been in operation ever since, though removed to Agincourt in 1898. The Earl of Rosse often consulted Grubb in the construction of his telescopes; indeed they were friends with kindred tastes. Grubb's most notable production was the famous four-foot reflector at Melbourne, Australia. Thomas Grubb retired from active work in 1868 and was succeeded by his son Howard, who extended the business, making many instruments, large and small. In 1918 the works were moved to St. Albans, England, in connection with the manufacture of periscopes, as the firm had made a specialty of those instruments. Many makers of scientific

instruments suffered in the aftermath of the war, amongst them the firm of Sir Howard Grubb and Sons. Sir Charles Parsons was interested, not only in the work of the firm, but also in its members and their family history, and it is pleasing to learn that in February, 1925, he acquired the business and the firm name became Sir Howard Grubb, Parsons and Co. Large and well-equipped shops were erected beside the turbine-electric works at Newcastle, and the firm was ready to construct astronomical equipment of the largest size. Since then some large instruments have been produced, including a 36-inch reflector for the Royal Observatory, Edinburgh; also a 40-inch reflector and a 24-inch refractor, with their revolving domes, for the new Stockholm Observatory. The order for the 74-inch reflector for the David Dunlap Observatory, to be erected near Toronto, was given in May, 1930, and it is to be regretted that Sir Charles did not live to see its completion. He was accustomed to the construction of mighty machines, some of them much larger than this instrument, but I believe he was thrilled with the prospect of producing a telescope excelling his father's masterpiece of 1845.

During his lifetime Sir Charles Parsons received many honorary degrees and medals. To enumerate them would take too much space, but three distinctions may be mentioned—F.R.S. in 1898, K.C.B. in 1911, and O.M. (Order of Merit) in 1927.

In 1883 Sir Charles married Katherine, daughter of W. B. Bethell, of Yorkshire. They had two children, a son, who was killed in 1918, in the war, and a daughter.

Sir Charles and Lady Parsons made many journeys together, including one to South Africa in 1929. Early in February last they started on a cruise to the West Indies. When some days out Sir Charles became indisposed, but nothing serious was suspected. On the 10th he seemed rather better and was able to sit on deck, smoking and chatting with his friends; but next day he became worse and quietly passed away at 8.30 p.m. on board ship, in the harbour of Kingston, Jamaica. The body was removed and taken back to England, where it was laid to rest with simple ceremony in the churchyard of Kirkwhelpington, on his estate about twenty-five miles north-west of Newcastle. Very appropriately a memorial service was also held in Westminster Abbey.

In closing my sketch of this great man I will quote a few remarks made by some who knew him much longer than I did.

DR. R. T. GLAZEBROOK, in *Nature*:—

No one meeting Parsons casually would have recognized in the gentle, modest man, somewhat quiet and hesitating in speech and manner, one of the world's great benefactors. In public he said little; but interest him in a problem, ask his advice on some knotty point of scientific or engineering practice, give him, perhaps, a little time for quiet thought, and your problem was solved, or if solution was not at once to be found, you were set on a track promising to lead to the desired end. Moreover, if the attainment of that end seemed of importance, you secured for the rest of your journey the support and assistance of a most wise counsellor and, what is more, a most kind friend.

J. HAZZELKUS, Managing Director, Ross, Limited:—

He was uncanny in his ability to lay his fingers on the weak spot of any contrivance which had been much thought of by its originator, and here his great charm of manner was in evidence, so that no man hesitated to lay his ideas before him, and all were always the richer for the advice and help unstintingly given. Sir Charles had ready almost at once not one solution only, but several, leading to embarrassment as to which of them to choose.

A SCIENTIFIC FRIEND in *The Yorkshire Post*:—

No one can ever know the range of his help to those who had fallen on hard days, but it was inevitable that from time to time instances should become known. Most striking of all in this connection was his solicitude for those who in pain or sorrow were nearing their end. He would spare no trouble to cheer their days in some thoughtful way. On receiving the Order of Merit he wrote, "I think the congratulations of one's old friends give far more pleasure than any honour"—no formal phrase, but sterling truth from him.

University of Toronto

GREEK SCIENCE

By Alice Willard Turner

TO trace the autonomy of science would present a very difficult problem, merged as it has been—and is—with philosophy, mythology and art. Greek science had initially a precarious existence; inasmuch as it did not affect economic conditions, it was developed spasmodically within the schools of philosophy. Indeed it is not until after the fifth century B.C. that we can even attempt a separation of mathematics, astronomy and biology, as sciences independent from philosophical speculations.

It is necessary to differentiate between mathematical and natural sciences, since only the former were thought capable of attaining to the Greek ideal of axiomatic science; that is to say, where a finite number of logical principles enables us to deduce rationally a number of truths, as a strict consequence. (*e.g.*, from the two propositions: (*a*) the sun is larger than the earth, (*b*) the earth is larger than the moon, we deduce (*c*) the sun is larger than the moon).

In every science the Greeks visualized a form and a matter. The form, which connects a consequence to its law in a necessary way, is found in every system of reasoned knowledge; but the matter varies according to the object peculiar to each science. Relative to matter, we have two groups. One is not directly related to sensation, as in mathematical facts; in this case our science can be rigorously constituted since the number of primary conceptions enables us to infer, by reasoned deduction, certain consequences. The second group gives rise to sciences based upon sensible observation, wherein the aim is to "discover the classification and natural hierarchies of phenomena in relation to one another."

The multifarious and tenuous divisions of each science to-day preclude the advisability or possibility of any exhaustive analysis, but we shall treat especially physics, biology, astronomy and mathematics proper.

The earliest known systematic advance on a mythological view of nature is to be found in the writings of Ionian philosophers, of whom Thales of Miletus is regarded as the first. Anaximander recognized rotary movements of the heavens round the pole star. and perceived that the dome overhead was but one half a complete sphere. In this way the earth was left free to float as a flattened cylinder within the celestial sphere. Next came the Pythagoreans, whose astronomical systems illustrate the purely mathematical character of their physical speculations. They simplified the previous conception by suggesting that the earth itself might be a sphere revolving about a central fixed point, at which they placed a universal fire. Somewhat later Aristarchus, under the delusion that the earth was greater than the sun, developed a heliocentric theory. Amongst all astronomers of this classic era, however, two names, Hipparchus and Ptolemy, enjoy unchallenged pre-eminence. Hipparchus's geocentric view determined the future of Greek astronomy, while Ptolemy entertained a similar large organic theory, relevant to epicycles, etc.

Simultaneously with the birth of astronomy, the problem of matter emerged. Empedocles' hypothesis of the four primary elements served to interpret phenomena for many centuries, and it is in these four elements that we trace the germ of atomism. Leucippus and Democritus developed the conception of Empedocles, by which he saw that a combination of the four different elements, in varying proportions, would explain the endless differences sensible matter presented, and the atomic theory was propounded. The destructive criticism of Aristotle was sufficiently influential to deprive this theory of a foremost place. Indeed, Aristotle's doctrine (or dogma!) that bodies are essentially light or heavy in themselves, persisted until Galileo's time. For the origin of mechanics, we must look to Archimedes, who formulated the fundamental conceptions of hydrostatics. Inasmuch as this science was incorporated in the "all inclusive" science of mathematics, we shall not deal with it further.

To the Greek, the word *βios* could have but metaphorical application to living things other than man. Nevertheless, the notions which we associate with the name are lucidly developed in Greek philosophy. Our information relevant to their significant

achievements in this science are derived from remnants of Hellenistic art. Vases of the sixth and seventh centuries B.C., "show a closeness of observation of animal forms that tells of a people awake to the study of nature." Habits of exact observation, which are the necessary basis of biology, thus characterize the Greek of this period.

According to the first systematic treatment of animals (5th century, Hippocratic collection), all animals consist of fire and water; nothing is born and nothing dies, but there is an eternal and perpetual revolution of things, thereby making change the sole reality. Man's nature provides a parallel to that of universal nature, and the arts of man are but an imitation or reflex of the natural arts. In this book a rough classification of animals is effected—especially refined in treating fish. Of greater importance, however, for subsequent biological development, are the anatomical and physiological descriptions which embrace mechanical explanations of bodily structure, comparisons between anatomical conditions encountered in related animals, systematic incubation experiments, theories of generation, and a theory of the inheritance of acquired characteristics. In a treatise on Nourishment (about 400 B.C.) we learn of the pulse for the first time, and read of a physiological system which lasted until the time of Harvey, with the arteries arising from the heart and the veins from the liver. We notice, moreover, that illustrations drawn from botanical study are rare in early Greek literature.

In the course of the development of Greek biological thought, Aristotle is the first great original thinker. In a very complete sense he is a vitalist, and requires for the exhibition of any phenomena of life the presence of a certain peculiar principle of a non-material character. Living things have a teleological import. In his theories of the development of the individual, Aristotle foreshadows an approach to an evolutionary doctrine. He based his explanations upon his fundamental doctrine of opposite qualities, heat, cold, wetness, dryness, which are found in combined pairs in the four prime elements. This theory, which was not displaced until quite recent times, was of the utmost importance for the whole subsequent development of science. An important factor in his teaching is that matter is continuous and not com-

posed of indivisible parts. For Aristotle, philosophy and science were theoretically linked together.

While all the surviving biological works of Aristotle refer primarily to animals, we are acquainted with his botanical attitude through the writings of his pupil, Theophrastus. With the latter's death, about 287 B.C., pure biological science substantially disappears from the Greek world. Science ceases to have the desire to know for a motive, and becomes, as an applied study, subservient to the practical arts. The greatest biologist of the late Greek period was Claudius Galen (A.D. 131-201), and his physiological views prevailed until and after Harvey.

In medical science the Greeks occupy a unique position. "It is the distinction of the Greeks alone among the nations of antiquity that they practised a system of medicine based not on theory, but on observation accumulated systematically as time went on." Diseases, in the Hippocratic view, are to be cured by the restoration of the disturbed harmony in the relations of the elements and humours.

The manifestation of Greek genius which a history of mathematics reveals is most impressive, and one to which the student of Greek culture is too often blind. Despite all the new developments in mathematics attributable to modern analysis, this science is destined to remain a Greek science, for it is the Greeks who "laid down the first principles, invented the methods *ab initio*, and fixed the terminology."

To appreciate the enormous and unprecedented contributions of Greek mathematicians we recall that their work was done in an incredibly short time, only with methods of pure geometry, supplemented by ordinary arithmetical operations. The words μάθηματα and μαθηματικός were not specifically appropriated to their ordinary meanings until Aristotle's time. Plato regarded *mathemata* as any subject of instruction or study, and in book VI. of the Republic, we find that the greatest *mathemata* is the Idea of the Good. With Thales, geometry first becomes a deductive science dependent upon general propositions. From this time to that of Pythagoras the progress of geometry is unknown. The special contribution of Pythagoras to this classic study is thus described in Proclus' summary: "After these Pythagoras trans-

formed the study of geometry into a liberal education, examining the principles of the science from the beginning, and probing the theorems in an immaterial and intellectual manner; he it was who discovered the theory of irrationals and the construction of the cosmic figures." The succession of geometers from Pythagoras to Plato is little more than a group of names, but we may mention Anaxagoras, Democritus, and Zeno of Elea.

The Greek classification of mathematics is an interesting one. In the Pythagorean quadrivium we have four branches, namely, geometry, arithmetic, astronomy and music. Logical grounds prompted Plato to make music or harmonics follow astronomy in his classification, for, as astronomy is the motion of bodies attracting the eye, so there is an harmonious motion which appeals to the ear. This dependence of musical intervals on numerical proportions led to the doctrine of the harmony of the spheres. Arithmetic, in the Platonic sense, denotes the science treating of numbers in themselves. This confinement to the theory of numbers presupposes the art of calculation (which is Arithmetic in our sense), as a propædeutic to the true science itself. As the science which treats of numbered things (as opposed to numbers), we have logistic. This division does not consider number in its essence, but has for its subject-matter everything that is numbered. The most elaborate classification of mathematics, however, is given by Geminus. Arithmetic and Geometry treating of the non-sensible or objects of pure thought, are followed by five branches of applied mathematics, *viz.*, mechanics, optics, geodesy, canonic, and logistic. The function of geodesy or mensuration is to measure, while canonic is the theory of musical intervals. Subdivisions of these branches are then effected, and the whole scheme acquires surprising complexity.

The first serious attempt to construct a philosophy of mathematics is to be found in Plato's Dialogues; herein the nature of hypothesis, methods of reasoning, and definitions are discussed. Although Plato probably contributed practically no original work in mathematics, his enthusiasm for the subject, together with the singularly pre-eminent place it occupied in his philosophy, have had an immeasurable influence upon its development. While Aristotle did not specialize in mathematics, as the immediate

predecessor of Euclid he is not without interest. It is not improbable that two of the supposedly Euclidean theorems relating to the theory of parallels are anticipated in his Posterior Analytics. Moreover, he elucidated certain general conceptions, such as the continuous and the infinite. To Euclid, of whom we know very little, remained the task of bringing to irrefragable demonstration those things which were only somewhat loosely proved by his predecessors. Euclid's Elements and Geometry now become identical. Other great geometers include Aristarchus of Samos (280 B.C.), who was the first to formulate the Copernican hypothesis; Erastosthenes, who measured the earth's diameter to within fifty miles of our present computations; and Archimedes. We might remark that Archimedes himself regarded his mechanical inventions and every sort of art directed to use and profit as ignoble, preferring rather the beauty and subtlety of pure geometry. With Apollonius of Perga, the eminent authority on conic sections, Greek geometry reached its culminating point. Until modern algebraical geometry substantiated this, little progress was possible, Subsequent developments lead us to trigonometry, advanced by Hipparchus and Ptolemy, to mensuration, connected with Heron of Alexandria, and to algebra, with which Diophantus of Alexandria (A.D. 250) associates himself. This brings us to the final stage of Greek mathematics, including chiefly commentators, and issues in Byzantine development.

A general purview of Greek science reveals certain dominant features. Initially we notice that paramount attention was paid to the laws of thought, and to an exhaustive examination of the essence of methods which lead to knowledge. The resultant methodology and characteristic rationalism cannot be overestimated.

The goal of all scientific work, indeed, was the determination of the essential nature of concepts; definitions and investigations aimed to arrive at ideas of an abiding nature as opposed to changing opinions. We remark upon the systematic character of their work, and in the organic articulation of science we notice the powerful concentration upon the conception of development. Science, as utilitarian, is merely accidental, and of subsidiary importance almost always. The Greeks were pre-eminently geometricians,

and the emphasis placed upon deductive methods may have hindered empirical physics. The scientist, in this period, seeks the intelligible, rather than the fact, and has more in common with the theoretical speculator than with the laboratory experimenter.

The attitude, which engendered such a searching analysis, and promulgated such an arbitrary hypothesis, could not have been other than a sceptical one; and those Greek sceptics who denied science did so chiefly because they thought too highly of it.

The abiding worth of Greek science, as of all Greek thought, is that they brought into clear consciousness and perfected for all time a methodology which has been the key to scientific knowledge.

RADIO TALKS OVER CFCT, VICTORIA, B.C.

By W. E. Harper

XXXVIII. Measuring the Speed of Light
(July 11, 1930)

SO often in the course of these ten minute chats have I had occasion to refer to the distance of some celestial objects in terms of light-years, that it seems almost necessary to say something about the velocity of light, on which this unit of distance is based. This astronomer's yard stick, the light-year, is simply the distance that light will travel in one year, going at the rate of approximately 186,000 miles a second. You may well wonder how it is possible to form any estimate of this great speed, much less accurately measure it, and so a few words on this topic may not be amiss.

One of the earliest determinations was made by a Danish astronomer, Roemer by name, from certain variations in the times of the eclipses of the moons of Jupiter. Almost every one knows of the four bright moons of Jupiter, since they are easily visible in an ordinary opera glass. The closest one to the planet revolves about it in 1 3/4 days; the outermost one of the four in 16 2/3 days. When in their orbits they pass into the shadow cast by the planet they are, of course, hidden from view and the times of these eclipses ought to occur with the utmost regularity, without even a second's deviation. But this Danish astronomer as he studied the times of disappearance found that there was a great variation in the times of eclipse for each of the moons and he ascribed this to the fact that the earth was not always at the same distance from Jupiter and that light actually took time to pass through space.

We can easily understand how the distance between our own planet, the earth, and Jupiter varies throughout the year. We are roughly 93,000,000 miles from the sun while Jupiter is about 483,000,000 miles, both revolving about the central body in nearly circular orbits. When we are both on the same side of the sun our distance apart is the *difference* of these two numbers but when

we are on opposite sides of the sun our distance apart is the *sum* of these two quantities. It is thus seen that in the first case we are 186,000,000 miles closer to Jupiter than in the second case, and as Roemer found the eclipses occurred about 16 1/2 minutes later when farthest away he rightly ascribed this lag in time to be due to the time required for light to cross the diameter of the earth's orbit. His value for the speed of light was in fair agreement with modern determinations and showed that he was an astronomer much in advance of his time.

There are certain difficulties, however, to contend with in securing the exact times of diappearance of the satellite and this method has been superseded by determinations made upon the earth. The problem is simply to send a flash of light over a known distance on the earth and by means of some mechanism for recording short intervals of time to obtain the speed.

The person who above all others has done this work with precision is Michelson of the University of Chicago. He is now, at the age of seventy-six, engaged in experiments on Mount Wilson, California, with the purpose in view of even improving his value for this important physical constant. Some earlier laboratory workers used a rotating wheel with toothed edges to determine the time interval. If the wheel has 1000 teeth and it makes 100 revolutions per second then the time between consecutive teeth passing in front of your eye would be 1/100,000 of a second. By controlling the speed of rotation of the wheel so that a flash of light which enters the open space between two teeth can travel a measured distance and, being reflected from a mirror, will return just in time to get through the next following opening you have all the data necessary for the determination of the speed of light.

Michelson, following the method of a French physicist named Foucault, early used the device of a rotating mirror whose sides, whether four, eight or twelve, were accurately constructed and optically perfect plane surfaces. At Mount Wilson a beam of light after reflection from one of the sides of the rotating mirror was sent to another mirror some 22 miles away on a neighbouring mountain whence it is returned over its outgoing path. In the meantime the rotating mirror has turned through an angle, the amount of which can be controlled by the speed imparted by the

rotating mechanism. The angle through which the mirror has turned will cause the returning beam to be deviated from its original path. The amount of this deviation being measured gives us a clue to the movement of the mirror and hence to the time elapsed between outgoing and incoming signals.

An improvement was obtained in his technique in 1924 wherein he controlled the speed of the rotating mirror, which was eight-sided, so that when the flash of light returned to the mirror the latter had moved in the meantime exactly one-eighth of a revolution. Thus another face of the octagonal mirror was in the identical position of its predecessor when the flash left on its outgoing trip and in consequence the light returned over its entire original path. By sending a number of flashes in rapid succession from a slit source illuminated by a powerful arc light one could, when the speed of the rotating mirror was adjusted perfectly, see the light on the distant mirror just like a star shining on the mountain side. Since the distance was accurately determined by the U.S. Coast and Geodetic Survey as 35,426.3 metres (about 22 miles) and since the rotation period could be obtained mechanically, thus furnishing the time interval, it was simply a process of dividing the distance by the time to secure the velocity. The value obtained was 299,796 kilometres or 186,285 miles per second, with an error probably not greater than 10 miles per second.

Just think what this velocity means. It means that light will flash between seven and eight times around the earth in one second of time. A ray of light leaving the sun will require about 8 1/3 minutes to reach the earth, it will require about 4 1/2 hours to travel out to Neptune or 5 2/3 hours to the newest planet Pluto, recently discovered at the Lowell Observatory. But these times pale into insignificance when we think of the journey required to reach the stars. The nearest star is so far distant that light travelling at this enormous speed requires four and a third years to cross the distance between us, and consequently we say it is 4 1/3 light years distant. Other stars are 50, 100, 1000 and some many thousand light years distant.

No wonder then, such importance is attached to the determination of the velocity of light, for upon it rests entirely our scale of distances in the universe.

XXXIX. Weighing the Stars

(January 20, 1931)

THE question has been asked me as to the sizes of the stars and how they compare with our earth as to size and mass. While the question might be answered in a sentence or two, I have thought that it would be of interest to give not only the answer but the methods by which astronomers are able to deduce the masses of the stars and other similar data.

We know that all bodies tend to fall to the earth. This we say is due to an attractive force exerted by the earth and called gravitation; and it is only a special case of a much more general law that any two particles of matter attract each other with a force which, to express it roughly, increases with the masses of the particles and diminishes with the distance between them. If you were to place two solid bodies a short distance apart on a frictionless surface you would find that they would eventually pull themselves into contact with each other. This is the same force that pulls the apple to the ground when its grip on the branch has become feeble.

To measure the mass of the earth, all that is necessary is to have a very sensitive balance with a double set of scale pans, one pair suspended a considerable distance below the other. Two masses which balance when placed on the upper pans will not balance if one be placed on the lower corresponding pan, since the attraction of the earth is greater at the decreased distance. The small mass that must be added to the other pan to restore the balance can be related to the total mass of the earth, which has thus been found to be of the order of 6×10^{27} grams. (In tons this would be over 6×10^{21}, or 6 followed by 21 ciphers, tons.)

Our earth is moving about the sun, being held to its path all the time by the gravitational pull of the sun's mass. If this attraction did not exist the earth would fly off at a tangent into space. From the known distance of the sun we can calculate what its mass must be to thus hold the earth in its orbit and we find it to be about 332,000 times that of the earth itself.

In the case of the stars we must confine ourselves to those which are known to be of binary character, that is, those which are composed of two bodies mutually revolving about each other.

Assuming that the law of gravitation holds everywhere throughout space, we can, from the known periods of revolution of double stars, deduce the masses they must have. It is necessary to know their linear distance apart, so that we can compare it with our own system of sun and earth. As the separations of double stars are always quoted in angular measure, that is, as so many seconds of arc, it is further necessary to know the distance of any double star system from us before we can convert the angular separations into linear distance.

But in various ways the distances of these double stars from us have been learned and we are thus enabled to say how many millions of miles apart the components are. We can then compare them with our earth-sun system and deduce from the observed period of revolution the corresponding masses which those components must have. In general they are of the same order as our own sun. Some are known with a mass of about one-quarter that of our sun whilst others are from that mass up to six or more times the mass of the sun. The great bulk of the stars fall within these limits as regards mass, although there are exceptions, such as in the intrinsically high-luminosity stars, where the masses are sixty or seventy times that of our sun. Whilst definite determinations are available only for these binary stars, we have no reason to suppose that the single stars are markedly different from them.

In regard to their sizes the stars vary widely. Whilst their masses may be roughly stated as being uniformly similar to that of our own sun their sizes vary more than a million-fold. In some stars the matter is densely packed; in others it is no denser than our atmosphere; in others again the matter comprising the star is so extremely tenuous that it may be likened to that in a highly exhausted vacuum. The companion of the Dog Star, Sirius, is exceedingly dense, being 50,000 times as dense as water. As it is almost as massive as our sun it must accordingly be only 1/500,000 as large. At the other extreme we have stars like the red giants which are enormously bulky. Betelgeuse, the reddish star in the shoulder of Orion, while probably not having more than twenty times our sun's mass is nevertheless unbelievably larger. Its diameter is at least 250 times as great, which would give it a volume 16,000,000 times that of our sun.

There is a theory regarding the formation of the stars which explains why they should be of fairly uniform mass. It appears that in the star of average mass the pressure of the gases outwards just nicely balances the force of gravity towards the centre. If at formation too much stuff found itself in one mass it would in time subdivide into two smaller masses.

Some indication of the mass of a star is given by its colour. If it is yellow like our sun, we may expect it to have about our sun's mass. If it is a bluish white star it will be more massive than our sun, ranging from equality up to five or ten times our sun's mass. If it be red it may fall in either of two divisions, those much less massive or those more massive. The reddish stars visible to the naked eye, however, are all of the latter class, ranging from equality up to ten times our sun's mass.

It is understood, of course, that all these figures are only roughly approximate.

XL. What the Sun is Composed of

(February 3, 1931)

ONE of my unseen audience two weeks ago, when I was speaking on the masses of the stars, was led to wonder just what the composition of the stars must be, since some are exceedingly dense whilst others are the very opposite. He asks if the dense ones are all metals, whilst the others are gaseous.

It has seemed to me, then, that I might describe the composition of our own sun, which is a typical star. The differences between it and other stars can be treated at another time. It is evident in the first place that the sun must be an extremely hot body to radiate so much heat to the earth across the millions of miles separating us. Let us take it, on faith for the present, that the temperature of its outer atmosphere is in the neighbourhood of 6000°C., a degree of heat that is beyond attainment in our electric ovens, although temperatures of 3500° can be attained in some of these. It does not require much thought to realize that the ordinary metals at that high temperature will, if present at all, simply be in the form of metallic vapours.

The only method we have of learning of the composition of the

sun is by the analysis of the light it sends to us. Almost everyone knows that white light, such as sunlight, is composite in character and can be separated into its component colours from red to violet by passing it through a prism. Nature's prism is the raindrop, for where sunlight streams through a shower of these drops we see on the background of the sky the rainbow in all its gorgeous colours.

When we study very closely any one of these colours in the spectral band of sunlight we notice that it is crossed by numerous markings or lines. Experimenting similarly in the laboratory with light from various sources, it is seen that markings likewise appear in the analysed light of whatever source be used. If a bit of iron is turned into vapour, a host of lines will appear in the coloured band produced from it and these will always be in a definite position, and will reproduce themselves faithfully on every occasion that iron vapour is used as the source of light.

By comparing the analysed light, or spectrum, as it is called, of iron vapour with that of the sun we find numerous lines coincident in position and similar in character in the two spectra and this leads us to conclude that iron in the form of metallic vapour is present in the sun's atmosphere. If one takes a photograph of the solar spectrum in this way and with the same instrument takes a similar photograph of the spectrum of iron vapour, he will find thousands of lines that will match in every particular. By examining various metals in turn and comparing their spectra with the solar spectrum it has been possible to establish definitely the existence in the sun's atmosphere of the vapours of most of the ordinary known metals.

The total number of elements is 92, the lightest being hydrogen and the heaviest, uranium. As a result of such comparisons as those just mentioned and from certain other evidence of a rather technical character the presence of 57 of these elements in the sun has been established. If there is much of the element present in the sun's atmosphere, we would naturally expect that the lines in the solar spectrum corresponding to that element would be both numerous and strong. Laboratory practice assures us such is the case. It is therefore concluded that silver, for example, whose lines in the sun are very few and weak, must be present in small amount. There need be no rush to stake claims on the sun for that

much sought after metal. On the other hand, elements such as iron, calcium and magnesium which show numerous strong lines must be relatively abundant. The lines most numerous in the sun are those of the following elements and in this order: iron, titanium, chromium, cobalt, nickel, vanadium and manganese—to name only the first seven on the list. Moreover, the lines of greatest intensity in the sun are those of the following elements: calcium, hydrogen, iron, magnesium, sodium and aluminium. The conclusion is strongly indicated that the order of abundance of the elements in the solar atmosphere is much the same as in the earth's crust.

Of the 35 elements not yet identified in the sun, 17 may be regarded as possible, and 18 as doubtfully possible of detection. The lines of these latter elements lie in regions of the spectrum inaccessible to us. There is no sufficient reason for believing, however, that any element known on the earth is absent from the sun. We may go further and state that it would appear that the elements with which we are familiar on the earth are present, in modified form of course, in the sun and in all the stars.

This analysis of sunlight gives us the composition only of a thin layer of the sun's outer surface, the atmosphere. The luminous sphere, called the photosphere, which we see as the disk, lies below, and as the light emanates from it, the elements in the atmosphere absorb their own particular lines, thereby revealing their presence to us as just described. The main body of the sun, of course, is much hotter than the exterior and it becomes increasingly hotter as we approach the centre. If we could register the temperature there, it would be found to be millions of degrees. Owing to the sun's great mass, the atoms in the central portions must be crushed beyond recognition.

XLI. Exploring the Upper Air

(February 17, 1931)

MANY of my unseen audience have doubtless heard of the mehods, used for several years now at meteorological stations, in which small balloons are sent aloft, equipped with instruments of small size to record the temperature of the upper air. By means of telescopes trained on the balloon as it rises, one can follow its

course and thence determine the direction and velocity of the wind in the upper atmosphere. When the balloon reaches a certain height it bursts, and by means of an automatic parachute arrangement the record is eased back to earth. A tag on it states that a reward will be paid for the return of the recording instrument, and a large percentage of them find their way back to the station.

From these devices we have learned much about the temperatures of the upper air. On the average, the air gets colder and colder with increase of height up to seven miles above sea level, where its temperature is about −67°F. For the next seven miles the temperature is practically constant with height. Beyond that it is largely conjecture but it will not long remain unknown if a rocket device now being tested out proves successful.

The rocket idea is not a new one, although newspaper readers will connect it more with a certain scientist who has been working for the past few years on the chances of being able to shoot one to the moon. The principle is common in artillery design and is becoming fashionable in the design of racing cars which hope to lower speed records. If a rocket can be constructed that can be shot up to 25 or 50 miles and at the same time be equipped with automatic recording instruments that would be just what we should desire. The feasibility of shooting one this high has never been seriously questioned but computation shows that the velocity would be so great that there would be very little likelihood of any delicate recording instrument withstanding the stress to which it would be subjected in its passage through the air.

The principle on which engineers are now working is to secure samples of the air at any desired height. By automatically sealing each sample where captured and returning it to earth, analysis in our laboratories would show its composition, its temperature and density. It is thus proposed to have the rocket carry a highly exhausted thin-walled vessel of suitable size surrounded by a constant temperature device. The vessel will terminate in a sealed tube which can be automatically broken and sealed again almost instantly. At the maximum height attained, a sample of air is thus secured and analysis in our laboratories will yield the density of the sample when captured, its temperature and its composition.

Newspaper reports indicate that a trial was to have been made a few weeks ago from a high peak in the Alps by an American scientist who resides in Vienna. To quote briefly from the despatch: "Dr. Lyon hopes his rocket to reach a height of from forty to fifty miles. It is twelve feet long, weighs 134 pounds uncharged, and is propelled by an explosive mixture of liquid hydrogen and liquid oxygen. The rocket contains a cylinder equipped with a parachute and instruments whereby it is hoped to procure samples of air at the maximum height, together with data regarding its density and composition." The plan has the endorsation of able meteorological physicists like Humphreys of the United States Weather Bureau and would seem to be quite feasible, particularly as Dr. Lyon has already been able to shoot a rocket to a height of fifty miles from the same place. In these latter trials, of course, the instruments were not attached.

Our present knowledge of the composition of the earth's atmosphere is to the effect that at the surface of the earth nitrogen constitutes about 79 per cent. of it and oxygen the remaining 21 per cent. About twenty miles up, which is about as far as direct observation has reached as yet, the proportions are about 85 per cent. nitrogen to 15 per cent. oxygen. Understand, of course, that these figures are approximate only as there are traces of other constituents, such as carbon dioxide, ozone, etc. It is surmised that at an altitude of about thirty miles both nitrogen and oxygen decrease in quantity and lighter gases such as hydrogen and helium take their places. On certain assumptions, it has been calculated that at a height of fifty miles nitrogen would form only 30, and oxygen only 3 per cent. of the atmosphere, the remaining two-thirds being largely hydrogen and helium.

If the rocket principle is successful it will be possible to obtain samples of air at any height from the earth's surface up to fifty miles. The analysis of such samples will be of great value, not only to the astronomer, but to the meteorologist in forecasting weather, and they may have a very direct bearing also upon radio broadcasting and reception. Of this latter phase of the question I may speak some time later, as I know every radio fan is interested in possible solutions of the static problem.

THE AGE OF THE EARTH*

By Georg von Hevesy

BEFORE inaugurating my lectures on this generous foundation established by Mr. George Fisher Baker, I would first of all express my pleasure at having this opportunity to spend a term with my colleagues and the students of this department, which has reached such a high degree of perfection under the able, far-seeing guidance and efficient administration of your genial director, Professor L. M. Dennis. The actuality far exceeds what I had come to expect from the glowing accounts given by my predecessors.

For my introductory lecture I have chosen the problem of the age of the earth. Our earth was born from our sun. The sun, while in the giant-star stage, is supposed to have been broken up by tidal actions induced by a passing star several times more massive than itself. Originally formed in the gaseous state, the earth passed to the liquid state through loss of heat by radiation from its surface, and later into the solid state. The earth's crust and some of its individuals were formed simultaneously, followed at a much later era by the formation of biological individuals. When did the earth's crust solidify? How many years then elapsed before "life" began to develop? These questions are of interest for both the physical and the biological sciences, and an answer will be sought in the following discussion.

Astronomy teaches that the various members of the solar system have originated from the same material. This conclusion is supported by the chemical analysis of meteorites, which not only contain the same elements in approximately the same proportions as in the material of the earth, but also show them in the same isotopic combination. The two nickels of atomic weights 58 and 60 are present in excatly the same ratio in iron meteorites as in terrestrial nickel. The silicon of the stone meteorites contains the three isotopes of atomic weights 28, 29 and 30 in exactly the same

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ratio as does terrestrial silicon. There can be no doubt that the material of the earth separated from the sun's mass and the cooling of the gaseous material led to solidification and the formation of minerals.

The sand-filled hour-glass is the simplest clock. If at any spot on the earth's surface sand were deposited at a fixed rate since the solidification of the earth, then the total amount of sand deposited by this geological hour-glass would indicate the age of the earth, if we could measure the rate of deposition and the volume of the sand. Such geological hour-glasses actually exist. Rivers carry salts to the sea and knowing the annual volume of salts carried down and the total salt content of the oceans, we can deduce the length of time this process has been in action. This interval of time corresponds to the age of the earth's crust. Even accumulations of sand itself are actually found in nature where rivers have brought sand, mud and sludge down to the sea and deposited them at the river mouth. A knowledge of the total thickness of the sediment and of the annual deposit therefore leads to a knowledge of the date of the beginning of the process. Professor Arthur Holmes, of Durham, to whom we are indebted for numerous important contributions to the determination of the earth's age, makes the following estimates for the maximum thicknesses of the sedimentary strata:

	Meters
Cenozoic Era (modern life forms)	24,000
Mesozoic Era (medieval life forms)	30,000
Paleozoic Era (ancient life forms)	61,000
Precambrian Era ..... at least	60,000
Total	175,000

We can form a general idea of the rate at which these sediments have been deposited. To take an illustration used by Sir James Jeans in his very stimulating volume "The Universe around Us," since Rameses II reigned in Egypt, over 3,000 years ago, sediment has been deposited at Memphis at the rate of one meter every 1,200 to 1,500 years. With geological strata deposited at an average rate of one meter per 3,000 years, the total 175,000 meters of strata listed above would require over 500 million years for their deposition.

At the much slower rate of one foot in 4,000 years,[1] the time would be about 2,100 million years.

As early as 1715 it occurred to the famous astronomer Edmund Halley that from its salt content one might calculate the age of the ocean and hence the age of the earth's crust. In that year he published a paper entitled "A Short Account of the Cause of the Saltness of the Ocean, and of Several Lakes that Emit no Rivers; with a Proposal to Help thereof to Discover the Age of the World." He showed that since the water removed from lakes by evaporation is perfectly fresh, "the saline particles brought in by the rivers remain behind, while the fresh evaporate; and hence it is evident that the salt in the lakes will be continually augmented and the water grow salter and salter." Applying the same principle to the oceans, he wrote: "It is not improbable but that the ocean itself is become salt from the same cause, and we are thereby furnished with an argument for estimating the duration of all things."

In Halley's time the necessary figures for such a calculation were lacking, but 184 years later when the same suggestion was made by Professor Joly, of Dublin, accurate data on the mass of the oceans, their sodium content and its yearly increase were at hand. The oceans contain 1,180,000 billion ($=10^{12}$) tons of water. The sodium content is 1.08 per cent. by weight, so that altogether there are 12,600 billion tons of sodium. Rivers annually contribute 35 million tons of sodium to the sea, and a simple calculation gives the age of the sea = (12,600 billion/35 million) = 360 million years. The salts which the condensing vapours of the magma directly led to the sea by volcanic processes, the amount of salt removed by wind-borne spray, and similar factors are neglected in these calculations. These factors can hardly influence the results to any very appreciable extent; but grave errors may ensue from our tacit assumption that the rate of our geological clock is the same now as it always has been. We assume that the salt additions to the sea and sedimentation proceed to-day at the same rate as yesterday and as ever. These assumptions are not necessarily true; there is definite evidence, indeed, that these regulating processes proceed now more rapidly than the average rate in the past geological ages.

[1] The present rate of subaerial denudation over North America is estimated at 15 cm, or about 6 inches, in 4,000 years.

We are now approaching the end of a geological period which is characterized by the formation of hills and rising continents. These conditions are favourable for the transportation of matter to the sea since the river gradients are steeper and the circulation of ground water more thorough. In the long geological ages of the past when the sea flooded the present lands and mountain elevations were consequently appreciably lower, exactly opposite considerations applied. This natural geological change is not the only reason for rejecting the assumption of a regularly running clock. Human activities tend to accelerate these time-keeping processes upon which our calculations depend. Man cultivates the land, cuts off and uproots the forests, and his industry brings large quantities of soil into the rivers. Many of the largest and geologically most active rivers such as the Ohio and the Mississippi flow through cultivated and thickly populated districts where formerly forests protected the land from erosion. The sodium gained by the sea in the past must, therefore, have been less than at present, and the age of the sea as estimated from its sodium content must be set correspondingly higher. Similarly, the age as estimated from the sediments must be also increased. The late Professor Barrell even succeeded in showing a definite rhythm in geological processes. He showed conclusively that most regions of sedimentation have been subject to alternate scour and fill, and that the actual thickness ultimately preserved is merely the balance left by these two processes.

Geological methods for determining the age of the earth as thus sketched evidently do not satisfy the most important assumption that the time-indicating processes proceed now at the same rate as they have always done in the past.

The astronomer as well as the geologist is interested in the age of the earth and has also applied his principles towards the solution of the problem.

The fate of the earth is bound up with the fate of the sun. If it were possible to determine the present age and the term of the life of the sun, then the same period is simultaneously the maximum possible life of the earth. The sun loses energy at the rate of 3.3×10^{33} ergs per second, and if we knew the source of this energy, it would be possible to calculate the time required for the sun to reach its present state. Helmholtz and Kelvin believed—in agree-

ment with the state of physical learning in their day—that the contraction of the sun provided its energy. A contraction indicates a segregation of material toward the centre and a consequent liberation of potential energy which would be converted into heat. Lord Kelvin calculated that the shrinkage of the sun to its present size could have provided energy for hardly more than about 50 million years of radiation in the past.

If these calculations are applied to the calculation of the age of other stars, it soon becomes apparent that the results obtained are untenable. δ Cephei, one of the variable stars, radiates 700 times as much heat as our sun. According to the above theories, this star should have decreased in radius by 1/300 since 1788 when it was first carefully observed, but the actual contraction is not more than 0.5 per cent. of the calculated value.[2]

In addition to these and other astronomical contradictions, numerous geological arguments oppose so low an age as 50 million years for the sun and the earth. Thus the contraction hypothesis must be rejected. Stellar energy must have some other source.

To-day we know that colossal energy is stored in the nuclei of the atoms, and this knowledge is one of the most important results of our modern study of the transmutation of the elements. It is most natural to assume that this large amount of energy is the source of radiation from the sun and stars. As the amount of stored-up energy of a star determines its length of life, modern astronomical theories through this nuclear energy just referred to arrive at a possible life-span for the sun several hundredfold that estimated by Kelvin.

The energy stored in the atomic nuclei can be set free in many ways. Radioactive decay, the dissociation of heavier into lighter atoms, sets free a comparatively small quantity of heat, although even this is many times greater than the heat developed by a normal chemical reaction. For example, the heat obtained from the decay of one gram of radium, which requires about 20,000 years for its practical completion, is 3.7×10^9 calories, which is equal to the heat of combusion of 500 kg of coal. Other processes, involving

[2]So large a change in its radius should have caused a change in the rate of oscillation of δ Cephei, but this has not been observed. This point is discussed by Sir Arthur Eddington in his illuminating book "Stars and Atoms."

the atomic nuclei, supply yet larger quantities of energy, namely, syntheses of the elements from the hydrogen atom.

The nucleus of the helium atom contains four protons, and consequently the nucleus of the helium atom should be four times as heavy as the hydrogen atom. This is not the case, however, for the helium atom mass is 0.8 per cent. less than that of four hydrogen atoms. The difference is due to the fact that during the formation of the helium nucleus from 4 protons and 2 electrons an enormous quantity of energy is set free and radiated. Now according to the theory of relativity a loss in mass corresponds to a loss of energy, although this is never noticed, as a rule, in ordinary chemical reactions on account of the extremely small mass which corresponds to one erg of energy. One gram of mass corresponds to the absolutely prodigious amount of energy of 10^{20} ergs.[3] The extreme ratio between the units of mass and energy will be more readily understood from the following example.

If 100 carloads of coal were burned to carbon dioxide, then the combustion of this million kilograms of coal would set free a large amount of energy, but the loss of mass due to the release of this huge amount of energy would be equivalent to only about 1 gram. In the processes of the atomic nuclei, however, the quantities of energy involved are so colossal that the resulting changes in mass are no longer negligible.

The difference in mass between one helium atom and four hydrogen atoms together with a number of similar values, thanks to Aston's marvelous experiments, are now known with great precision, and these enable us to calculate the energy set free by the formation of a helium atom from the four protons and in similar atomic reactions. Such syntheses are the sources of extraordinarily huge amounts of energy.[4]

Radioactive disintegration is the transformation of heavier elements into lighter ones, and is a well-studied phenomenon, but very little is known about synthesis, the reverse process.

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[3]According to the special theory of relativity, the relation between mass and energy is given by $E = c^2m$, where c is the velocity of light.

[4]The accurate value, as determined by Aston, for the loss of weight when helium is synthesized from hydrogen is 0.00724 per gram of hydrogen.

In the Cavendish Laboratory at Cambridge and in other research institutions like Professor Harkins' Laboratory in Chicago, the disruptions of the nuclèi of light atoms under bombardment by alpha-particles have been studied. It was found that a minute proportion of the alpha-particles was successful in disrupting the nuclei, and some of the successful particles remained in the nucleus of the bombarded nitrogen atom. The latter lost a proton (mass 1) and gained an alpha-particle (mass 4), the actual increase in mass being 3. The nitrogen atom was thus converted into an isotope of oxygen (atomic number $7-1+2=8$). It is to be presumed that a building up of synthesis of heavier elements from lighter ones takes place on a large scale in some unknown part of the universe.

Radioactive decays and the synthesis of the elements from hydrogen constitute two sources of enormous energy that were unknown to Kelvin and his contemporaries. Furthermore, the sources of energy are not yet exhausted The mass can even completely disappear and be converted entirely into energy. When a helium nucleus is synthesized from protons and electrons 3×10^{18} ergs of energy are released by the annihilation of only 0.8 per cent. of the mass of hydrogen involved; but if the *total* mass of hydrogen be destroyed the energy set free is 125 times as great.

Thus we recognize three sources of energy which may be responsible for the radiation of the sun and other heavenly bodies, viz., in order of magnitude: radioactive decay of the heavy elements; synthesis of the elements from hydrogen; complete transformation of matter into radiation. The ratio of the wealth of these sources is roughly 1:1,000:100,000. A uranium sun decaying to uranium lead thus can provide only a thousandth part of the energy supplied by a hydrogen sun transforming itself to helium, and only a hundred thousandth part as much as a sun whose mass is completely transformed to energy. In this way we arrive at very different values for the upper limit of the age of the earth, according to which of these possibilities is employed in our calculations. A uranium sun would have a life-period of only 100 million years; a hydrogen-helium sun would have a life of 10^{11} years, and a mass-energy sun (the third type) of 10^{13} years. The first value is certainly too small, for the earth must be younger than its parent the sun and we shall see that the earth is certainly older than 100 million years. Astro-

physics also entirely supports this conclusion. Radioactive change can not be the sole source of the sun's radiation.

There are definite astrophysical arguments against the assumption that the sun's centre or the material of the stars contain more than 10 per cent. of hydrogen, and these have been discussed by Eddington in his book on "Stars and Atoms." In the event that the source of the sun's energy is the synthesis of higher elements from hydrogen, the above value for its age must be reduced to 10^{10} or 10,000 million years.

The leading astrophysicists regard the assumption of atomic synthesis from hydrogen as insufficient to explain the astronomical phenomena, and they are inclined to the view that the aging of a star consists, to a large extent, in the annihilation of its original mass and its transformation into energy. The simultaneous destruction of 10^{3} protons and electrons per gram of the sun's material per second would suffice to account for the loss of energy by radiation and would secure a continuation of the sun's radiation for 10,000 million years.

It is, perhaps, essential to point out here that just as Kelvin's calculations were vitiated by the less complete state of scientific knowledge at that time, so the same fate can overtake our present calculations. Science is compelled, however, to base its concepts on the contemporary state of knowledge, and nothing makes greater demands on the intuitive and critical faculties of the scientist than the estimation of how far the possible explanations of a phenomenon are exhausted, even when possible future developments are considered.

Nevertheless, and bearing this possible fate fully in mind, we now consider that the knowledge acquired from the study of atomic transformations not only constitutes one of the greatest advances of science but also very probably exhausts the possible sources of the sun's energy.

Geological methods give a lower limit to the possible age of the earth, while astrophysical methods supply an upper limit. The geological clock runs too slowly and the astrophysical too fast. One of the many beautiful achievements of radioactivity is that it has provided us with the necessary magic clock whose accuracy and reliability leave nothing to be desired, and—for us the most impor-

tant specification—whose rate has remained constant since the solidification of the earth's crust.

Single atoms of uranium and other radioactive substances explode. The number of particles exploding and decaying in unit time is strictly proportional to the number present. For instance, from 10^{15} uranium atoms (4×10^{-7} gm), 1,000 atoms decompose in 5 days; and from 10^{14} atoms there decompose 100 in the same time.

Uranium decay is the desired strictly uniform process whose velocity has remained unchanged throughout geological time, for it is the nucleus which is involved in the decay, and nuclear processes proceed independent of temperature, pressure and other external conditions. Therefore, there is absolutely no reason to believe that the process has gone forward at any different rate than at present at any period in the earth's history. The study of radioactivity with its inexhaustible applications has provided further proof that uranium and other radioactive substances have always decomposed in the past with the same velocity as at present. The decay of a uranium atom is always accompanied by the radiation of an alpha-particle. These alpha-particles, which leave the atom with a velocity of 8,800 miles per second (or about one-twentieth of the velocity of light), can travel a certain distance or work on a photographic plate, colour mica, glass and other substances within a certain fixed limit from their place of origin.

Beyond this distance, called the range, which in air is about 2.8 cm and in mica about 0.013 mm, the velocity is so small that the alpha-particles are powerless. In nature certain micas such as biotite and muscovite inclose minute uranium-containing crystals. The alpha-particles from these inclosed uranium atoms, in the course of geological ages, have evidently coloured the mica over a quite definite area. Some decomposition products of uranium also emit alpha-particles, but these have a different velocity and a correspondingly different range so as to form a ring of different diameter in the mica. The sections of these coloured circular areas exhibit the property of pleochroism under polarized light and for this reason were called "pleochroic halos." The diameters of these halos are closely related to the velocity of the decomposition of the radioactive atom from which the alpha-particles originate, as has been experimentally demonstrated; therefore, a change in the rate of

decomposition of the radioactive substances during geological time would correspond to an alteration in the diameters of the halos. The halos corresponding to the various radioactive substances have in every case the same diameter, from which it can be concluded that the rate of decay has remained the same throughout the ages. Hence the decay of uranium provides us with a process going on at a strictly uniform rate. To use this rate of uranium decay as a measure of time, however, it is necessary to know two facts: (1) the total quantity of uranium that has decayed in some mineral since the solidification of the earth, and (2) the rate of that decay.

(1) One helium atom originates from the decay of each uranium atom. This helium collects in the uranium-containing rocks and its volume gives the number of uranium atoms that have decomposed since the formation of the rock. (2) The production of 1 cubic centimetre of helium from 1 gram of uranium requires 9 million years. A knowledge of the uranium and the helium content of a rock gives, therefore, its age. According to this method the age of the rocks has been computed to be 570 million years. Although the rocks store a large part of the helium which is produced in them, a small portion gradually escapes in course of time so that the values obtained by this method give only a lower limit for the age of the earth. Fortunately, in addition to the helium accumulated in the rocks we may also measure another and this time a solid product which can not escape, namely, lead. Uranium decay leads also to the production of lead, and we need only determine the lead content of the uranium minerals in order to be able to calculate what proportion of the uranium has decomposed since the mineral was formed. The following table shows the rate at which uranium decays and uranium lead is formed:

Initially:			1 gm uranium		No lead
After	100 million years	.....	0.985	"	0.013 gm lead
"	1,000 " "	.....	0.865	"	0.118 " "
"	2,000 " "	.....	0.747	"	0.219 " "
"	3,000 " "	.....	0.646	"	0.306 " "

These figures refer solely to the chief quantity of uranium, namely, uranium I, which amounts approximately to 97 per cent. The lead which has originated from uranium need not be confused

with any accessory lead because uranium-lead has a lower atomic weight (206) than either ordinary lead (208) or actinium-lead (207).

When this lead method is applied to a great number of uranium-containing minerals we obtain the following ages of the geological eras:[5]

Geological age	Age in years
Late Oligocene	37 million years
Permo-carboniferous	204 " "
Late Precambrian	587 " "
Middle Precambrian	987–1087 " "
Lower Precambrian	1257 " "

The lead method leads therefore to the result that the Precambrian minerals were in existence even 1,260 million years ago, and therefore the solidification of the earth's crust must have already taken place, perhaps about 1,400 million years ago.

The lead method has proved to be of great importance because its application enables us to determine not only the age of the oldest minerals but also the lower limit of the age of the earth's material and consequently of the chemical elements. The transformation of uranium into lead had already progressed to a certain point while the earth's material was still gaseous. The lead (206) so produced did not remain isolated as such, however; it had opportunity at that stage to mix with the thorium lead (208) from thorium decay and as a result common lead (atomic weight 207) was produced. Hence approximately half of our common lead was formed from uranium before the earth's materials had solidified. The ratio of all the uranium to about half of the common lead (plus the uranium lead) present in the whole earth's material must give the age of the earth's material. To a certain extent we can regard the whole earth as a colossal uranium- and lead-containing mineral. From this standpoint we consider not only the lead now existing as pure uranium lead or thorium lead, but also that other lead which

[5]Holmes and Lawson calculated these ages from the uranium, thorium and lead content of minerals, using their approximate formula:

$$\text{Age} = \frac{z}{x + 0.38\,y} \times 7{,}400 \times 10^6 \text{ years.}$$

They denoted by z the grams of lead present in the mineral, by x those of uranium and by y the grams of thorium. As thorium is usually associated with uranium, the thorium present must be, in practically every case, taken into account.

was produced as uranium, thorium or actinium lead but has ceased to exist as such on account of mixture with thorium lead in the gas-liquid earth. Such a mixing of practically chemically identical elements, the so-called isotopes, was a common occurrence and must be the explanation for the fact that, for example, chlorine always has the same atomic weight. In whatever form chlorine occurs in nature there is always the same ratio between its two isotopes Cl (35) and Cl (37). The lead which has been produced in uranium minerals has had no such opportunity to mix with thorium lead, and consequently it has remained fixed as uranium-lead. H. N. Russell first drew attention to the fact that by such a method as the above the upper limit of the age of the earth could be calculated, but at that time it had not been proved that ordinary lead is a mixture of uranium-lead and thorium-lead. Since then Aston has succeeded by means of his mass spectrograph in showing that normal lead is chiefly such a mixture. These outlined considerations give about 3,000 million years as the upper limit of the age of the minerals and the lower limit of the age of the earth's *material*. During this huge period, it is only the few radioactive elements, decaying according to accurately known laws, that have altered; the other elements which build up the earth's constituents have undergone no change.

Formerly one was inclined to make no distinction between the radioactive and non-radioactive elements, and to believe that elements of the latter class were also transformed, although extremely slowly. Aston's beautiful experiments have shown, however, that this is not so. The heavy radioactive elements decay with an energy loss, whereas in the synthesis of the lighter elements from protons or alpha-particles energy is set free. Thus there is a basic difference between the radioactive and the non-radioactive lighter elements.

All the minerals and rocks which have been subjected to tests by the helium and lead methods have been taken from the earth's crust, since samples from the centre of the earth are not obtainable. When the geochemist desires to know details of the composition of the interior of the earth, he turns to the meteorites and makes the assumption that iron meteorites correspond to the iron core of the earth and the stone meteorites to the more or less silicate layer.

On account of experimental difficulties, only the helium method has hitherto been applied to the determination of the age of meteorites. The disadvantage of this method, that the helium can escape from the sample in course of time, is here without significance since the iron meteorites even when heated to a red heat lose no trace of helium. In recent years my predecessor in this lectureship, Professor Paneth, has developed the methods for helium determination to such an extent that one can measure 10^{-7} cubic centimetres of helium, and he has carried out determinations of the ages of meteorites. He has found for the iron meteorites a maximum age of 2,600 million years. This result lends additional appreciable support to the theory that the meteorites and the earth were formed from the same stellar material.

We can follow the fate of the earth's materials back for about 3,000 million years and show that, except for the few radioactive substances, the elements have undergone no change in the course of these years. How and to what extent the individual elements have appeared and disappeared in the span of about 8 million million years between the creation of the sun and the creation of the earth remains, however, hidden from us. Astronomers estimate the sun's age as about 8 million million years.

The study of radioactivity has led us to the above conclusions. Scientific research attemps to discover and to explain the connections of the natural phenomena. The most fascinating feature of such research is that the experimenter never knows whither the developments may lead. When Bequerel discovered radioactive rays, he had no idea that his discovery would lead to an efficient method for determining the age of the earth. The action of X-rays caused a green fluorescence of the glass walls of his tubes and Bequerel wished to determine whether all fluorescing substances sent out X-rays. Thus he discovered the action of uranium on a photographic plate and hence the radioactive rays. Continuing Bequerel's work, Pierre and Marie Curie were led to study the activity of uranium-containing minerals and discovered in pitchblende the presence of an element radiating much more strongly than uranium, namely, radium. The radioactive rays and radium were indeed epoch-making discoveries; but the most important contribution to the science of radioactivity was made by Rutherford

and Soddy when they recognized that radioactive radiation was merely a subsidiary phenomenon accompanying the transformation of uranium and the other radioactive elements, and that it indicated a *disintegration of the atom*. They pointed out that the disintegration products must be present in uranium minerals and accumulate in the mineral in the course of time. Boltwood, who did so much for the early development of radiochemistry, studied a series of uranium minerals, and the constant ratio of uranium to lead struck him as remarkable. He concluded that lead was the end-product of the uranium disintegration and was the first to suggest that the uranium-lead ratio could be employed for the determination of the age of the earth. Simultaneously, the present Lord Rayleigh showed how the accumulation of helium in the uranium minerals furnished a method of determining their age. Experimental and theoretical researches by many workers were necessary in order to extend especially the lead method and to lead to the well-established numerical values here given.

The age of the earth according to ordinary time standards is enormous, but when compared with the age of some stars our earth is extraordinarily young. Three different astronomical methods can be applied to the calculation of the age of the stars, and all three astronomical clocks show the same time, 5 to 10 million million years. If the age of a human being is 1 second, of the human race 6 hours, then the lower limit of the age of the earth is one year, and the age of the stars is 5,000 years.

REVIEW OF PUBLICATIONS

Probabilités et Statistiques par R. Montessus de Ballore. Pages viii, 211, 6½ × 10 in. Paris: Hermann et Cie, 1931. Price, 60 francs.

The aim of the Author is to represent a statistical series by the terms of the binomial law of probability, that is to say, by non-exhaustive drawings from an urn with a given composition. This law is presented to the reader as the "formule de probabilité simple" which a unique statistical phenomenon is assumed to satisfy. Shall we have to see the mysticism of the normal law superseded by the mysticism of the "simple law?

Long since, Pearson* solved precisely the same problem. Later on,† he gave a method of representing a law of probability by exhaustive drawings from an urn, that is to say, by the terms of a hypergeometric series. Instead of taking the moments for the complete series as Pearson does, the Author places the origin at the abscissa of maximum frequency and uses the moments of the frequencies with positive and negative abscissae respectively. Thus, he has only to consider the truncated moments of orders zero, one and two: in this consists the originality of the book. At the end of the volume, the reader will find the solution of a problem of grouping: a binomial law being given, its terms are added n at a time, the question is to find a second binomial law giving an approximate representation of this new repartition.

After the epoch-making work of Charlier and Pearson on the analytical representation of a law of probability, the Author's method has but little interest. The statistical series representable by the binomial law are nearly as exceptional as the statistical series representable by the normal law. The Author himself gives several examples of impossibility. Besides, there may be some objections against the systematic representation of a continuous

*Karl Pearson. Contributions to the Mathematical Theory of Evolution." II Skew Variation in Homogeneous Material. *Phil. Trans.*, Vol. 186 A, 1895. Not quoted by the Author.

†Karl Pearson. On certain Properties of the Hypergeometrical Series, and the fitting of such Series to Observation Polygons in the Theory of Chance. *Phil. Mag.*, Vol. 47, 5th series, 1899.

law of probability by the binomial law which is essentially discontinuous. If we consider that the statistician is practically sure to obtain an excellent representation if he uses the Pearsonian curves and is theoretically sure to have a perfect analytical representation if he chooses the Charlier expansions, we are led to the conclusion that, if these methods can be improved, it is not in the direction taken by the Author.

J. CHAPELON.

Four-Figure Tables of the natural and logarithmic trigonometrical functions, with the argument in time, by L. J. Comrie. 32 pages, $7\frac{1}{2}\times10\frac{1}{2}$ inches. 4 shillings. Obtainable from the Author, Nautical Almanac Office.

These tables supplement the standard four-figure mathematical tables recently published by Milne-Thomson and Comrie. They give the values of the natural and logarithmic trigonometrical functions with the argument in time. They will be frequently of use in astronomical computations. For the first twenty minutes for $0^h\ 0^m$ to $0^h\ 20^m$ the interval of the argument is one second, which makes interpolation easy and accurate. For the rest of the table the interval is ten seconds of time. All six trigonometrical functions are tabulated for the natural functions. The natural functions and the logarithmic functions are tabulated on the same page. I think this an improvement over the usual method of making two distinct tables.

R. K. Y.

The Stars in Their Courses, by Sir James Jeans. 188 pages, $5\times7\frac{1}{2}$ inches, with 47 plates and 2 star maps. Toronto: The Macmillan Company of Canada, 1931. Price, $2.00.

Few scientific publications have achieved the popularity enjoyed by the two recent books by this author. The present work grew out of a series of radio talks given in England, and the original material has been expanded to twice its length. The style is informal and conversational, with many picturesque and striking illustrations of the significance of some results obtained by astronomers. Sir James Jeans is best known to the scientific world as an able investigator in the field of cosmogony, and this aspect of the

subject is very prominent here. Within three pages (132-4) is given a "History of the Universe;" and the sub-headings of Chapter VIII are, A Model of the Universe, The Finite Universe, The Expanding Universe, A Stampede of Nebulae, The Size of the Universe, The Substance of the Universe. In an appendix there are hints to assist in locating the stars, and tables of the planets.

The present writer would question the correctness of statements on page 3, ll. 8, 9 from bot.; page 104, top paragraph; page 105, bottom paragraph; and misprints were noticed on pages 15, 23, 50, and 134.

C. A. C.

CORRECTION TO ARTICLE ON PLUTO

Regarding the article on Pluto in our February number (p. 64), Professor H. N. Russell writes to the *Scientific American*, as follows:—

I much regret that, owing to an error in the preliminary carbon copy of the paper on the mass of Pluto, which Dr. Nicholson generously put at my disposal, one of the statements in my recent article failed to report his final conclusions.

If the earlier observation of Lalande is disregarded, the remaining observations of Neptune are insufficient for any precise determination of the mass of Pluto. If Lalande's observation is included, Dr. Nicholson's value is as stated. A different estimate of the accuracy of this early observation would lead to a different value of the probable error of the final result.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Attendance at the Chicago Planetarium

The Adler Planetarium in Chicago was opened for visitors on May 12th, 1930, and until March 9th, 1931, there the attendance was 648,670, or upwards of 2000, on the average, per day. The book-stores also report a greatly increased demand for books on astronomy, all of which indicates a healthy growth of interest in the heavens. Up to December 31st, 1930, the seventeen Planetariums then in operation, had been visited by 4,505,000 people. In a few months the Fels Planetarium in Philadelphia will be completed and it is reported that one will be provided by Los Angeles. It is to be hoped that Canada will secure one in the near future.

Doings at Mount Wilson

The report of the Director of the Mount Wilson Observatory for the year 1929-30 shows that a multitude of researches in diverse fields of astrophysics are in progress there. A brief outline of the problems being attacked would occupy many pages, but the following extracts give a few of the results attained:

The 200-inch Telescope.—The Observatory has contributed throughout the year in many ways to the progress of the plans for the 200-inch telescope. . . . Several of the 22-inch fused silica discs made by the General Electric Company in the course of its experimental work on the methods to be employed in the manufacture of the 200-inch disc and the auxiliary mirrors have been figured in our optical shop and tested under a wide variety of temperature condition with most interesting results.

The 50-foot Interferometer.—The adjustment of the 50-foot interferometer and tests of its optical performance are being made by Pease with satisfactory results. Fringes have been observed to a distance of 34 feet, and the mechanical operation of the instrument is in general excellent.

Observations by the Public.—Public interest in the use of the 60-inch telescope for visual observations on Friday evenings has increased steadily, and 6,621 visitors have used the instrument during the year. About one-half of this number were high school and college students. The public lectures on these evenings have been continued regularly by W. P. Hoge of the Observatory staff. Many thousands of visitors have made use of the opportunity afforded daily to view the astronomical exhibit under the charge of J. O. Hickox, and to inspect the operation of the 100-inch telescope.

The Planet Pluto.—In the winter of 1919, M. L. Humason made with the Cooke 10-inch photographic refractor a series of photographs centered on the ecliptic in a search for the trans-Neptunian planet predicted by W. H. Pickering and Percival Lowell from the perturbations of Uranus and Neptune. The fields observed covered the positions predicted from all the mathematical solutions. In the following year the search was continued with the 60-inch reflector, but the observations were limited to a zone one and one-half degrees wide on either side of the ecliptic. The photographs were examined with an improvised "blink" comparator, but the planet was not detected, although many asteroids and a few variable stars were observed. The most careful examination naturally was made in the immediate neighbourhood of the ecliptic.

After the announcement of the discovery of the new planet by the Lowell Observatory, Nicholson undertook the re-examination of the 10-inch refractor plates, but it was not until the area to be covered could be limited by means of appropriate positions of the orbit plane and two provisional ephemerides that he was able to find the images of the planet. They appear on four of the negatives within 1° of Pickering's predicted longitude, but at a distance of nearly 4° from the ecliptic in a portion of the Milky Way extremely rich in stars.

The positions of the planet as measured on these photographs, together with positions from observations made by Mayall in March and May, 1930, with the 60-inch reflector, and the Lowell Observatory positions of January, 1930, were used by Nicholson and Mayall in a computation of the orbit. The resulting period was found to be 252 years; the eccentricity of the orbit 0.26; the semi-major axis 40 astronomical units; and the time of perihelion passage 1988.6.

Temperature of Mars.—A new reduction of the observations on Mars, made in 1924 with a thermo-couple having small receivers for exploring the image of the planet, gives for the temperature of the sub-solar point at perihelion 294°K (70°F). The observations of 1926 reduced to perihelion give 297°K (75°F). The great eccentricity of the orbit would make the temperature at aphelion 27° lower.

ANCIENT AND MODERN

1300, B.C., Egypt—Rameses II,. Ra-her-aakhuti, the Mighty Bull, beloved of Maat, lord of the Vulture and Uraeus Crowns, protector of Egypt, fetterer of the countries, the Golden Horus, strong one of the years of victories, King of the South and the North, User-maat-Ra, Governor of governors, begotten by Tem, one with him in substance, to make his sovereignty to be upon the earth for ever, provider of the House of Amen with food, the son of Ra, Rameses, beloved of Amen, the ever-living.

1931 A.D., Siam—Prajadhipok, king of Siam, of the North and South, and of all the dependencies, of the Lactians, of the Malays, of the Earens, descendant of the great god Buddha, supreme

arbiter of the ebb and flow of the tide, brother of the Moon, half-brother of the Sun, and possessor of the four and twenty golden umbrellas.

King Prajadhipok and his consort, Queen Bambai-Durni, are now in America. Their portraits show them to be orientals with westernized dress, very natural and human young people. In the Cairo Museum one can still see the mummy of Rameses, who, after a long reign, during which it is believed he oppressed the Israelites, passed away, as other human beings did.

Some things change very little with the centuries.

ASTROLOGY REVIVED?

One might well ask the date at which the following was written—whether 1000 B.C. or 1000 A.D. It might easily be either, but as a matter of fact, it is from a book by a learned writer published in 1931.

> We are told that astrology is a pseudo-science, although it has been developed entirely on the lines of experiment and experience and accurate records of facts. This development does not make it an exact science, but it is impossible not to be struck with the general accuracy of the readings of a large number of the characters of men and women which are based upon the readings of horoscopes. There are living among us parents who have had horoscopes made immediately after births of their children, and who bring up their children according to the directions supplied by the horoscopist. Similarly there are medical practitioners who have horoscopes of the patients made, and who use the information derived from them as a guide to the treatment which they eventually prescribe for their patients. Among one's friends and acquaintances are many men and women who have their horoscopes made annually, and who plan their work and travel and pleasure in accordance with the positions of the planets and the Signs of the Zodiac at the Vernal Equinox. . . .The results which astrologers obtain sometimes are so remarkable, and their prognostications are so often fulfilled to the letter by subsequent events, that even the unbeliever is compelled to admit that there must be "something in it". . . .Of all the things which have driven man in all ages to invent and to use magic, the most potent is the "Evil Eye" or the "Evil Look". . . .We may accept the view, which is based on the general experience of mankind, that envy can, and does, impart to the eye some quality which emanates from it and works evil upon the person or thing on which it falls.—From *Amulets and Superstitions*, by Sir E. A. Wallis Budge.

Referring to the statement above that "many men and women plan their work and travel and pleasure in accordance with the positions of the planets and the Signs of the Zodiac at the Vernal

Equinox," it may be remarked that the Signs of the Zodiac always have the same position at the Vernal Equinox, and hence the lives of these people should be the same from year to year!

The reason for the above quotation must surely be that its distinguished author has so devoted himself to deciphering hieroglyphics and other difficult languages of antiquity that he has not absorbed the essential facts or ideas of modern science.

Really, there seems to be a recrudescence of astrology at the present time. At a recent meeting of the Victoria Centre of the R.A.S.C. a resolution was passed asking the local newspapers to cease printing horoscopes. Also, over a nation-wide radio broadcast one can regularly hear a torrent of harmless platitudes and meaningless ambiguosities about the sun, the moon and the planets. Indeed from this and some other extensive broadcasts one would almost think that the salvation of the western world depended on—toothpaste!

Not long since, one evening, the present writer's telephone rang and a woman's voice asked:

"Can you tell me what month Saturn comes under?"

"I do not understand you; what is it you want?"

"Saturn is a planet, isn't it?"

"Yes."

"What month does it come under?"

"Saturn has nothing to do with any month."

"O-o-oh!"

C.A.C.

MEETINGS OF THE SOCIETY

At London

February 15, 1931—A social meeting of the London Centre was held at the home of Mr. J. C. Middleton, Base Line Road, London. There were forty-two people present. The following were elected to membership in the Society.:

Miss Alberta Tory, 517 Princess Ave., London.

Miss Hildegarde Webb, Byron, Ont.

Outside observations had been planned but weather conditions were unfavourable. A constellation contest was conducted by Dr. H. R. Kingston, after which Dr. H. S. Wismer gave a brief review of Sir James Jeans' recent book, "The Mysterious Universe." The remainder of the evening was spent under the delightful direction of Mr. Middleton and his capable assistants—his niece, Miss Middleton, of Toronto, and Mr. and Mrs. Francis Hallet. Games and music were enjoyed, refreshments were served, and everyone pronounced it the most successful of all the happy social events enjoyed by the London Centre.

March 13, 1931—A regular meeting of the London Centre was held in the East Lecture Room of the London Life Building. There were sixty-nine people present.

The following were elected to membership in the Society:

Mr. C. J. Fitzgerald, B.A., Box 1098, Brampton, Ontario.

Mr. D. M. Hennigar, 12 Gerrard St., London, Ont.

Miss Jane Steele, 61 St. George St., London, Ont.

The usual observation period was conducted by Mr. T. C. Benson. An unusually fine chart, showing on a large scale the constellation Leo and adjacent constellations, had been prepared by Mr. Benson. The Millikan view of the Jeans-Millikan controversy was presented by Dr. H. S. Wismer.

President McKone next introduced the speaker for the evening, Dr. R. C. Dearle, Head of the Department of Physics, University of Western Ontario. Dr. Dearle paid tribute to Dr. Wismer for his able presentation of the Millikan theories; the speaker suggested that the members of the Society keep their attention focused on the Jeans-Millikan discussion for the next few years; he predicted a complete revolution in physical science if the Millikan view point prevailed.

Dr. Dearle introduced his subject "Recent Investigations on the Aurora Borealis" by referring briefly to the Polar Year which is to be observed in 1932 throughout the astronomical and physical world.

The first scientific "guesses" as to the nature of the Aurora were based on its general appearance. The auroral effect may be produced by driving high speed cathode rays (or electrons) through a rarefied gas. The resulting coloured light is due to the destruction of molecules of the gas under the high speed electron bombardment. This led Störmer in 1923 to formulate the theory that the

Aurora was a cathode ray phenomenon; the upper layers of the earth's atmosphere were constantly subjected to bombardment of cathode rays discharged between the magnetic poles of the earth. The sun was regarded by Störmer as the source of these cathode rays. Dr. Dearle pointed out that Störmer's theory was a qualitative, rather than a quantitative, theory.

During the winter of 1922-23, Vegard had been examining the Aurora spectroscopically, and he found certain lines and bands which were characteristic of the spectrum of nitrogen, and two or three other lines not characteristic of nitrogen, in particular a green line of wave-length 5577A. Vegard's nitrogen dust theory followed his discovery of this green line: Nitrogen in a very finely divided state exists in the earth's atmosphere at a very low temperature, and the bombardment of electrons from the sun produces the auroral spectrum, including the green line. The Vegard green line was later shown by Prof. J. C. McLennan of Toronto to be merely an oxygen line which had been produced by Vegard when he opened up his camera to get more light.

In 1929 the most logical theory of the cause of the Aurora was given by Dr. Hulburt of Washington, who regards the Aurora as produced by the discharge of high speed electrons of terrestrial origin. The ultimate cause of this electron discharge is ascribed to eruptions on the sun, which produce a tremendous release of ultra-violet energy. This energy is absorbed in the lower layers of the earth's upper atmosphere, and electrons are shot away from the earth with a velocity of 100 kilometers per second. The fast moving electrons travel a distance of 1000 kilometres before they come into the field of the lines of force which lead back to the earth at about 25° from the north magnetic pole. As soon as the electrons enter a region of atmosphere which is sufficiently well condensed, the phenomenon known as Aurora Borealis is produced. It is well known that the maximum auroral effect occurs at about 25° from the north magnetic pole. Dr. Dearle concluded his lecture with the statement that the loud crackling or hissing noise which is popularly supposed to accompany an auroral display is a psychological effect rather than a physical one.

Immediately following the lecture, the auroral effect was demonstrated by Mr. Gar Elson, M.A., Research Assistant, National Research Council of Canada. Three Geissler discharge tubes were employed; one filled with nitrogen, one with oxygen, and the other highly evacuated.

A vote of thanks to Dr. Dearle and Mr. Elson for the informative lecture and demonstration was proposed by Mr. Wendell Holmes; enthusiastic applause showed the approval of all present.

G. R. MAGEE, *Secretary Treasurer.*

AT VICTORIA

March 24, 1931—(Extract from Minutes). Rev. Robert Connell delivered a lecture on "Some Geological Notes on Vancouver Island—Canada's Most Westerly Mountain Range." The lecturer explained that the mountains of this island are of the same age and origin, and hence are called a range. It was further explained how that they are part of a long range extending from

Alaska to California, with a valley on the east which is in some places below sea level and in some places above. Continents are floating in basalt, and, like icebergs, have movement, which accounts in some places for the change in the relative levels of land and sea.

The lecture was listened to by a large audience, many of whom had questions to ask Mr. Connell.

P. H. HUGHES, *Secretary.*

AT TORONTO

March 10, 1931—A regular meeting was held in the Physics Building of the University at 8 p.m.; Mr. R. A. Gray in the chair.

Mr. A. R. Hassard's description of Cancer was very interesting and instructive.

The lecture for the evening was on "The Energy of the Sun" by Professor D. S. Ainslie, Ph.D. At this time of the year when everyone is anxiously looking forward to the incoming of warm, sunny days, it is interesting to consider some of the facts science has revealed regarding the energy of the sun. On account of the fact that the amount of sunlight absorbed by the atmosphere varies so much from time to time, the actual measurements of the sun's energy made under many different conditions are employed to estimate the amount which would be received per unit area perpendicular to the sun's rays, if there was no atmospheric absorption. The heat energy of this amount of solar radiation per square yard is sufficient to raise the temperature of one gallon of water through $6\frac{1}{2}^{\circ}$ in one minute. If this were all converted into mechanical energy it would be equivalent to work at the rate of over four million horsepower per square mile. On the average about one-half of this amount penetrates to the earth's surface. When we consider that the sun is over ninety million miles distant from the earth, we realize that the amount of energy emitted from the sun's surface is stupendous.

The proportion of visible light in the energy radiated by the sun is about four times greater than from our most efficient electric lamps. The surface of the sun is one hundred and ninety thousand times as bright as a candle.

Nearly all sources of heat, light, and energy employed by man have been derived indirectly from the sun's energy. The heat derived from wood and coal represents energy of the sunlight stored up by the plants or trees in years gone by. The electrical energy of the Hydro derived from the waterfall at Niagara represents work done by the sun in the evaporation of water and the formation of clouds, which are driven hither and thither by wind currents supplying the sources of rain that feed the rivers and lake systems of which Niagara is a part.

One of the most fascinating problems in this connection is the explanation of the sources of the enormous amounts of energy which the sun has radiated out over the very long period it has existed. No doubt part of the energy has been derived from the contraction of the material of which the sun is composed, but this explanation is unsatisfactory from many standpoints, and workers in astronomy are still busy studying other possible explanations.

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Its objects are to study astronomy and cognate subjects, to publish the results of its work, and to maintain a library.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ont.; Winnipeg, Man.; and Victoria, B.C. Among its 800 members are a number of leading astronomers and scientists of the world, many amateurs, and, in addition, many laymen who are interested in the culture of the science.

The Society publishes a monthly JOURNAL containing each year about 500 pages of interesting articles and a yearly OBSERVER'S HANDBOOK of about 80 pages, containing valuable information for the amateur observer. Single copies of the JOURNAL or HANDBOOK are 25 cents.

Membership in the Society is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00 (no further dues). Publications are free to the members, or may be subscribed for separately.

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The library and offices of the Society are at 198 College St., Toronto, Ont. Applications for membership or for further information should be addressed to a local secretary (see back of this page) or to the General Secretary at the above address.